Module A

Mass Wasting Assessment

By:

Julie Dieu, Ph.D.
Rayonier

Table of Contents

List of Tables

List of Maps

MODULE A
MASS WASTING ASSESSMENT

1.0 INTRODUCTION

The purposes of the Mass Wasting Assessment are to identify the landslide processes that are active in the Palix Watershed Administrative Unit (WAU) and to determine which of those processes have been accelerated by forest practices. To accomplish these tasks, the assessment generally followed the methodology described in Version 3.1 of the *Standard Methodology for Conducting Watershed Analysis* (the Watershed Analysis Manual; Washington Forest Practices Board [WFPB] 1996). Deviations from the Watershed Analysis Manual methodology are explained in Section 3.0.

Through the use of text description and maps, this report addresses the nine critical questions listed in the Watershed Analysis Manual (WFPB 1996):

- What are the potential sediment sources in the basin?
- Is there evidence of, or potential for mass wasting in the watershed?
- What mass wasting processes are active?
- How are mass wasting features distributed throughout the landscape?
- What physical characteristics are associated with these features?
- Do landslides deliver sediment to stream channels or other waters?
- Do forest management activities create or contribute to instability?
- What areas of the landscape are susceptible to slope instability?
- What is the relative contribution of sediment from mass wasting compared with other sources?

All of the forms and maps recommended by the Watershed Analysis Manual (WFPB 1996) for the Mass Wasting Assessment were either used, modified, or excluded as follows:

Watershed Analysis Manual product title		**Corresponding product used in this report**	
Form A-1	Mass wasting inventory data	Appendix A-2	Mass wasting inventory data
Form A-2	Mass wasting map unit description form	Appendix A-3	Geomorphic map unit descriptions
Form A-3	Mass wasting summary table	Table A-1	Summary of land use or origin of mass wasting events
		Table A-2	Summary of landslide types
Form A-4	Summary of mass wasting and delivery potential (optional)	Synthesis Matrix	
		Text discussion in Sections 4.0 and 5.0	
		Map A-3	Mass wasting hazard
Map A-1	Landslide inventory	Map A-1	Mass wasting events
Map A-2	Mass wasting map units and potential hazard rating	Map A-2	Geomorphic terrain units
		Map A-3	Mass wasting hazard

2.0 GEOLOGIC OVERVIEW

The Palix WAU lies in the center of the area of land that hydrologically drains to Willapa Bay, a large, shallow, inland seaway in southwest Washington State (see Palix Watershed Analysis Vicinity Map in the Introduction section of this watershed analysis). The Palix River drains approximately two-thirds of the area delineated as the Palix WAU; several smaller streams that drain directly to Willapa Bay—Pickernell and Bruceport creeks and the Niawiakum and Bone rivers—are also included in the WAU (Map A-1, Appendix A-1). The confluence of the three forks of the Palix River is less than 1 mile from the head of the Palix estuary, well downstream from the upper extent of tidal influence (see Map E-2, Module E—Stream Channel Assessment). For this watershed analysis, the forks are called the North Palix, Middle Palix, and South Palix; however, local residents and many maps refer to the Middle Palix as the Canon River. The Pickernell Creek subbasin includes Pickernell Creek and a smaller creek that lies just to the south (Map A-1, Appendix A-1). The smaller creek is unnamed on the US Geological Survey (USGS) Nemah Quadrangle, but for this watershed analysis it is called South Pickernell Creek.

The northern and western portions of the Palix WAU are underlain by Quaternary terraced sediments (Walsh et al. 1987). Across the southwest quadrant of Washington State, these are described as "Silt, sand, and gravel of diverse compositions and origins, such as proglacial outwash, glacial outburst deposits, older alluvium, lahars, and uplifted coastal marine and estuarine deposits" (Walsh et al. 1987). There is no evidence of either glaciation or explosive volcanism in the Palix WAU (i.e., proglacial outwash, glacial outburst deposits, and lahars are unlikely sources), and outcrops of the terraced sediments reveal well sorted, poorly indurated, layered silt and sandstones (i.e., older alluvium is unlikely). If the rock was of estuarine origins, at least some newly exposed outcrops would be pale green, as is typical of unoxidized estuarine deposits, and some rock would contain little rusty spots where pyrite oxidation has occurred. However, the rock is pale yellow or pale brown, never green, and does not contain rusty spots. Thus, the terraced sediments in the Palix WAU are probably uplifted coastal marine deposits.

The Miocene Saddle Mountains Basalt, part of the Columbia River Basalt Group, underlies a small ridge in the northwest corner the Pickernell Creek subbasin (Section 3, T12N, R10W), surrounded by the lower standing Quaternary terraced sediments (Walsh et al. 1987). The southeast corner of the Palix WAU is underlain by Eocene basalts of the Crescent Formation, prevalent to the north of the Palix WAU on the Olympic Peninsula (Walsh et al. 1987). These basalts are described as "Fine-grained, dominantly submarine tholeiitic basalt flows and flow breccia, typically with zeolitic or chloritic alteration; pillows and altered palagonite common; . . . probably originated as mid-ocean ridge basalt and as seamounts" (Walsh et al. 1987). This description very aptly fits outcrops in the Palix WAU.

The western Willapa Hills in the Palix WAU appear to have been tectonically stable during the recent geologic past. Low-gradient valleys extend far inland to near the ridgeline of the Palix WAU. Channel gradients exceed 2 percent for only very short distances from the low valley bottoms towards ridgeline. The valleys are filled with Quaternary alluvium, the fourth geologic unit present in the WAU (Walsh et al. 1987), suggesting that net transport of material from the hillslopes to the estuary is limited. The landforms in the Palix WAU are predominately convex, both vertically and horizontally, suggesting that large-scale mechanical erosion (i.e., mass wasting) is not a significant process. Further evidence of this lies in observing the deep weathering profiles, often exceeding 20 ft in both the sedimentary and igneous rock. Without recent uplift, the hillslopes of the Palix WAU have eroded into stable, convex landforms with deep soils and limited natural mass wasting.

3.0 METHODS

A complete mass wasting inventory was completed using 1:12,000 scale (approximately) aerial photographs from 1955, 1963, 1970, 1982 (color), and 1993. The mass wasting events were mapped at 1:24,000 on mylar printed with the Washington State Department of Natural Resources hydrolayer and the Rayonier road layer and overlain on USGS quadrangle maps (Map A-1, Appendix A-1). Several data were recorded for each observed event: Years Observed, Delivery, Land Use or Origin, Landslide Type, and Geomorphic Character (Form A-1, Appendix A-2). The site of each landslide was examined on photographs from subsequent years, and the analyst noted whether the site was getting better (revegetating), getting worse (enlarging), or remaining the same. The first photograph year in which a landslide had completely revegetated is not recorded on Form A-1. For example, Mass Wasting Event No. 7 was first identified on the 1955 photographs, remained unchanged on the 1963 photographs, had experienced partial revegetation on the 1970 photographs, and had completely revegetated on the 1982 photographs, so "55, 63, 70B, --" is recorded in the Years Observed column of Form A-1. This level of detail was collected because it provides information about the severity of surface erosion after a mass wasting event.

From the topography and the aerial photographs, a map of geomorphic terrains was developed (Map A-2, Appendix A-1) following the system developed by J. Sasich (1994) for the *Big Quilcene Watershed Analysis*, used by J. Sasich and J. Dieu (1995) for the *Sol Duc Pilot Watershed Analysis*, and used by J. Dieu and B. Shelmerdine (1996) for the *North Fork Calawah Watershed Analysis*. The geomorphic terrains, also called geomorphic map units (GMU) delineate areas of similar bedrock or environment of deposition, degree of channel dissection, steepness, and process. The parameters of delineation, such as hillslope gradient of greater than or less than 65 percent, are chosen to best separate areas where mass wasting and surface erosion processes are more active from areas where they are less active. Thus, the watershed can be stratified into units that have distinct susceptibilities to, and rates or frequencies of, erosional processes, as well as distinct sensitivities to natural disturbances and management activities. Considered in this way, the watershed can be viewed as coarsely stratified by mass wasting and surface erosion hazard. The GMU that have significant mass wasting potential were delineated based on characteristics of sites where mass wasting had been noted in the inventory (i.e., landforms that looked like inventoried mass wasting sites but had not been observed to fail during the historic photograph record were also mapped). The GMU are similar to the mass wasting map units (MWMU) developed by other analysts but are systematically used for each new watershed analysis (e.g., MWMU 1 may be a completely different landform in each watershed analysis, but GMU 56 will represent the same landform across western Washington).

A mass wasting hazard map (Map A-3, Appendix A-1) was created by identifying certain GMU as Low hazard and identifying specific polygons of other GMU as Low, Moderate, or High hazard. The Low, Moderate, and High hazard calls for polygons of GMU that have significant mass wasting potential were determined through Synthesis and include consideration of deliverability and channel vulnerability.

4.0 RESULTS

Mass wasting, by either natural or anthropogenic triggers, has not been a dominant hillslope process in the Palix WAU during the historic photograph record, nor has it caused significant channel impacts anywhere except within the Middle Palix and Canyon Creek inner gorges. Only 74 mass wasting events were found during the inventory. By comparison, more than 600 mass wasting events were found for the same historic period of photograph record during the inventory of the North Fork Calawah WAU (Dieu and Shelmerdine 1996), which is only about 75 percent of the size of the Palix WAU.

4.1 MASS WASTING INVENTORY

Thirty-two of the 74 mass wasting events inventoried in the Palix WAU were triggered from road edges (fillslope failures). Only 9 of these, 28 percent, appeared to deliver (Table A-1). Failures from the seacliff edge of Willapa Bay numbered 21; 14 were apparently natural events, and 7 occurred in the first decade after clearcut harvest to the seacliff edge. All of these delivered, although the biological impact is presumably small and local. Seven inner gorge failures appeared to be quite old on the 1955 photographs and occurred along channel segments where splash damming had been done during the 1920s. These are attributed to undercutting triggered by the splash damming but could have been natural events. Seven failures occurred in clearcuts. Of these, 5 were small and did not deliver to any channel and 2 were larger and did deliver. Failures triggered from landing and gravel pit sidecast, selective harvest, road-altered hydrology, and natural failures were observed, but in very small numbers (Table A-1). Overall, 55 percent of the events delivered to fish-bearing waters; however, if the 21 seacliff failures are factored out, delivery to fish-bearing waters was 38 percent.

Table A-1 Summary of land use or origin of mass wasting events.

Land use or origin	No. of events	No. delivered	Percentage delivered
Fillslope failure	32	9	28
Seacliff failure; natural	14	14	100
Seacliff failure; clearcut	7	7	100
Splash damming (?)	7	7	100

Table A-1 (continued).

Land use or origin	No. of events	No. delivered	Percentage delivered
Clearcut	7	2	29
Landing failure	2	0	0
Gravel pit sidecast	2	2	100
Selective harvest	1	0	0
Road hydrology	1	0	0
Natural	1	0	0
Totals	74	41	55

Shallow, rapid failure was the most common landslide mechanism, accounting for 40 of the 74 inventoried failures. Delivery was unusually high, 65 percent, for these small landslides, but when the 17 shallow-rapid seacliff failures were factored out, delivery dropped to 39 percent (Table A-2). Fourteen debris slides, somewhat larger than shallow, rapid failures, were inventoried; 21 percent of these delivered to fish-bearing waters. Thirteen debris flows occurred. These probably initiated as debris slides and evolved into larger, more fluid failures as they traveled downhill. Delivery was 46 percent, and delivery volumes were probably quite large. Seven slumps were inventoried. Because many of these were triggered by stream undercutting, delivery was high, 71 percent. Of the four failure types, debris flows have the greatest potential for significant resource damage, both because of their likelihood to deliver to fish-bearing waters and because of the large volumes of soil they mobilize.

Table A-2 Summary of landslide types.

Landslide type	No. of events	No. delivered	Percentage delivered
Shallow, rapid			
All	40	26	65
Non-seacliff	23	9	39
Debris slide	14	3	21
Debris flow	13	6	46
Slump	7	5	71

4.2 GEOMORPHIC TERRAINS

To effectively map the Palix WAU, six GMU were chosen (Appendix A-3). GMU 60, areas of undifferentiated fluvial deposition (i.e., valley bottoms), was delineated because it limits delivery of mass wasting events. GMU 58, low-gradient (< 65 percent) areas of weakly dissected, undifferentiated bedrock, was delineated to distinguish areas of low mass wasting hazard from areas of higher mass wasting hazard. GMU 59, low-gradient (< 65 percent) areas of moderately to highly dissected, undifferentiated bedrock, was delineated because these areas are a dramatically distinct landform on the aerial photographs. When contrasted with GMU 58, GMU 59 is quite highly dissected and has very sharp ridges dividing the dissections. It poses no more deliverable mass wasting hazard than GMU 58, but midslope roads are likely to have much greater deliverability of surface erosion fine sediment. Most of GMU 58 and most of the northern polygon mapped as GMU 59 are formed of the Quaternary terraced sediments. The large southern polygon of GMU 59 closely approximates the extent of the Eocene Crescent Basalts present in the Palix WAU.

GMU 56, steep (> 65 percent) areas of moderately dissected, volcanic bedrock, and GMU 92, structural inner gorges, have been delineated to enclose all significant mass wasting potential in the Palix WAU. These GMU enclose all significant (i.e., sizable and delivered) mass wasting events observed in the historic aerial photograph record except seacliff failures. GMU 56 and 92 are also extrapolated to other areas of similar landform where significant mass wasting processes have the potential to occur. GMU 56 is composed of the steeper areas of GMU 59 and is distinctly steeper on aerial photographs and on USGS quadrangles. GMU 92 delineates the hazardous portions of the inner gorges found in the Palix WAU. These are structural inner gorges—those that are formed by stream downcutting into bedrock. The non-hazardous portions of the inner gorges are broad, convex slopes that pose little mass wasting hazard but are part of the inner gorge system in the sense that they contribute to the confinement of the river.

One small polygon of GMU 52, steep (> 65 percent) areas of moderately dissected, sedimentary bedrock, was delineated in the Palix Headwaters subbasin. This delineation was done following Walsh et al. (1987), but it seems unlikely from aerial photograph observations that this small area is underlain by other than the Eocene Crescent Basalts. For all management purposes, GMU 52 may be treated as GMU 56.

4.3 MASS WASTING HAZARD

The first draft of Map A-3, Mass Wasting Hazard (Appendix A-1), was done using Geographic Information System (GIS) directly from the geomorphic terrains. GMU 58, 59, and 60 were assigned Low hazard calls, and GMU 52, 56, and 92 were assigned Moderate hazard calls. Then, the areas assigned Moderate hazard calls were individually assigned Low, Moderate, or High hazard calls as determined during Synthesis. For example, GMU 92 has a moderate potential to produce significant mass wasting events, and there is a high likelihood that these events would deliver to the stream below. Channel Segments 2 and 3 have a High vulnerability to coarse sediment, so GMU 92 along these segments has been assigned a High hazard call (compare Map A-3, Appendix A-1, with Map E-1, Module E—Stream Channel Assessment, and see Synthesis Matrix Table 36). As another example, polygons of GMU 56 in the headwaters of the North Palix subbasin have been delineated as Low hazard because Channel Segments 37h, 37f, and 37b (Map E-1, Module E—Stream Channel Assessment) are Headwater channels delivering to non-fish-bearing, Forced Riverine Wetland channels (Map E-2, Module E—Stream Channel Assessment, and Map F-1, Module F—Fish Habitat Assessment) that will prevent coarse sediment from reaching fish habitat (see Synthesis Matrix Table 14).

5.0 CONCLUSIONS

Overall, mass wasting is not a significant mechanism of erosion in the Palix WAU; it occurs almost exclusively in GMU 52, 56, and 92 and along the seacliffs. In the limited areas of GMU 52, 56, and 92 where frequency of failure can be increased by forest practices, landslides can only deliver to fish-bearing waters if not captured in the upper reaches of the wetland channel system. The seacliff failures do not appear to be triggered by current forest practices. Observations of aerial photographs suggest that in the past the frequency of failure was increased in response to harvest to the edge of the seacliff, but that the requirements of the Shorelines Management Act have been sufficient to prevent this response.

Mass wasting in GMU 92 has been triggered by timber harvest but most often (apparently) has been triggered by splash dam undercutting. Roads have not been built within GMU 92 in the Palix WAU, but a dramatic response could be expected.

Mass wasting in GMU 56 has been triggered by loss of root strength following timber harvest and by sidecast failures from roads. Field observations of several of the largest failure sites suggest that failures initiate from unchanneled headwall areas that are 100 to 300 ft across and of 70 to 85 percent slope gradient. Failures can evolve into debris flows and travel down headwater channels until gradients drop below 15 percent. Deposition will occur in the first few hundred feet after the stream gradient lessens. Most of the largest failures initiated from road fillslopes where the road crossed the headwall area without relief drainage. Only one observed failure was triggered by clearcut harvest; this is not considered to be an important trigger.

There are several mechanisms of sediment introduction to the stream channels of the Palix WAU. The processes of hillslope surface erosion and mass wasting each contribute small amounts of fine sediment, and some coarse sediment, to the channel network. Each of these mechanisms probably provides a smaller contribution than do soil creep processes. The natural background calculations done by the Surface Erosion analysts suggest that natural soil creep contributes large volumes of sediment to the channel network (Table B-5, Module B—Surface Erosion Assessment), primarily because of the deep soils in the Palix WAU. Furthermore, their road erosion calculations indicate that road erosion processes are delivering more sediment to stream channels than are soil creep processes in many subbasins (Table B-6). Therefore, road erosion is probably the largest sediment source, and mass wasting is a much smaller and, except locally, an insignificant contribution.

6.0 CONFIDENCE

Several years of complete aerial photograph coverage for the Palix WAU exist between 1955 and 1993; five of these years were chosen, and all of the photographs were examined for landslides. Much of the WAU was harvested for the first time during the period of historic aerial photograph record, in particular the steeper landforms and ridgetops where mass wasting is more likely to occur. Road building and harvest practices of the 1950s and 1960s have been observed to trigger many more landslides than do forest practices of the past two decades (e.g., Dieu and Shelmerdine 1996), so it is reasonable to believe that if forest practices could trigger significant mass wasting in the Palix WAU, then evidence for this would have been observed during the very thorough photograph review of the era of first clearcut harvest. For these reasons, the analyst has high confidence that the landforms capable of deliverable mass wasting have been identified by the mass wasting inventory.

Delineation of the GMU is also believed to be very accurate. Map A-2 (Appendix A-1) was drawn using the mass wasting inventory, the USGS topographic quadrangles, and multiple photograph years so that the landforms could be clearly observed without the distortion of canopy cover. GMU 52, 56, and 92 have appearances very distinct from those of the other landforms, so confidence is high that they were accurately mapped.

Finally, the assignments of Low, Moderate, and High hazard calls to individual polygons of GMU 52, 56, and 92 were made following lengthy discussions with the entire team during Synthesis and with good understanding of channel types and channel processes in the WAU. In fact, the Stream Channel Assessment (Module E) and the Mass Wasting Assessment were closely linked by analyst cooperation in conducting field surveys together. Further field work since the time of Synthesis suggests that, if anything, the hazard assignments err in the safe direction.

7.0 REFERENCES

Dieu, J., and B. Shelmerdine. 1996. Sedimentation. *In* North Fork Calawah watershed analysis. Rayonier Timberlands Operating Company, Hoquiam, Washington.

Sasich, J. 1994. Geomorphic terrains of the Olympic National Forest. *In* Big Quilcene watershed analysis. Olympic National Forest, Olympia, Washington.

Sasich, J., and J. Dieu. 1995. Sedimentation. *In* Sol Duc pilot watershed analysis. Olympic National Forest, Olympia, Washington.

Washington Forest Practices Board (WFPB). 1996. Standard methodology for conducting watershed analysis under Chapter 222-22 WAC, Version 3.1. Timber/Fish/Wildlife Agreement and WFPB, Olympia, Washington.

Walsh, T. J., M. A. Korosec, W. M. Phillips, R. L. Logan, and H. W. Schasse. 1987. Geologic map of Washington, southwest quadrant. Washington Division of Geology and Earth Resources, Geologic Map GM-34, Olympia, Washington.